Collaborative Early Systems Engineering: Strategic Information Management Review

Prepared for the Center for Systems Engineering

by the Air Force Institute of Technology

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Executive Summary

Current Department of Defense (DoD) strategy highlights the need for information sharing and system interoperability as an essential requirement to support the needs of near-term and future war-fighting capabilities. Weapons systems fielded by the U.S. Air Force are conceptualized and delivered by the Air Force product centers. This report examines the Air Force product centers and provides a roadmap for future integration success. In July 2010, Air Force Institute of Technology (AFIT) Associate Professor, Alan R. Heminger, Ph.D. engaged graduate students at AFIT to explore these issues with a focus on Early Systems Engineering (ESE) initiatives led by the Center for Systems Engineering (CSE). These initiatives fall under an umbrella which the CSE has labeled collaborative early systems engineering (CESE). The AFIT research team generated this report to provide the CSE with refined, actionable, way-ahead recommendations for developing and implementing CESE across the Air Force product centers. The findings and recommendations produced from this study are listed below.

Findings:

1. The Air Force Product Centers appear to be operating in Weill's diversification operating model. Characteristics of this model include low business process standardization and low business process integration. There are a number of characteristics that the product centers display that support this conclusion. Among those characteristics we found the following:
    a. Each center has a unique culture
    a. Each center has a specific mission with distinct functional requirements
    b. Each center works with different contractors and customers
    c. Each center uses different business processes, standards, and technology
    d. Each center is geographically separated from the others
    e. Each center has a different organizational structure

2. From the standpoint of enterprise architecture (EA) the product centers are in the business silo stage. At this stage, each center's information stores and tools serves its own local needs. Sharing across centers is not a realistic option at this stage.

3. CSE initiated participation in the Development Planning working group; however, its involvement is still early.

4. CSE has initiated working groups.

Recommendations:

1. The product centers should consider moving toward a Coordination Operating Model.

2. The product centers should consider the stage of their enterprise architecture, with a goal of moving from stage 1, the Business Silo stage to stage three, Optimized Core, or stage four, Business Modularity to support the need to develop interoperable weapon systems.

3. The Center for Systems Engineering (CSE) should become the vehicle for coordinating the effort to move the product centers toward a coordination operating model and an enhanced enterprise architecture stage.

4. CSE should consider working with the product centers to establish a plan with scheduled milestones for moving toward compliance with the new DoD policy/guidance regarding information sharing and interoperability.

5. CSE should consider furthering its involvement in the Product Center working groups.

1. Introduction/Background

PROBLEM STATEMENT

Current Department of Defense (DoD) strategy highlights the need for information sharing and system interoperability as an essential capability of new U.S. weapon systems. Achieving this goal will enhance the ability of U.S. warfighters to meet the demands of, and dominate over, a rapidly changing threat environment that appears to be the norm for the foreseeable future. However, to make this objective a reality, it will take a unified effort by all weapons system development centers, both within each service and across the DoD. The Air Force Product Centers represent an area where this focus is needed. The product centers include: Aeronautical Systems Center (ASC), Electronic Systems Center (ESC), Nuclear Weapons Center (NWC), Air Armament Center (AAC), and Space and Missile Systems Center (SMC). These Centers are responsible for the full lifecycle, from creation to completion, of all weapons systems developed for the Air Force. Their ability to work together is critical to providing the information sharing and interoperability required by the DoD. This report examines the Air Force product centers from the standpoint of information sharing and potential for developing interoperability and provides a roadmap for future integration success.

PURPOSE

In July 2010, the Center for Systems Engineering (CSE) contacted Dr. Alan Heminger, Associate Professor at the Air Force Institute of Technology (AFIT) to help advance Early Systems Engineering (ESE) initiatives led by the Center for Systems Engineering (CSE). Dr. Heminger supervised a team of graduate students at AFIT to undertake this task. This initiative falls under an umbrella which the CSE has labeled collaborative early systems engineering (CESE). Over the past year, AFIT teams have investigated current CESE processes, tools, cultural issues, and knowledge management capabilities across the Air Force Product Centers. The current AFIT research team generated this report to provide the CSE with recommendations for developing and implementing CESE across the Air Force Product Centers.

THE TEAM

This research team worked under the direction and guidance of Dr. Alan Heminger, (AFIT faculty) and Lt Col William O'Connor (CSE). The team members consist of United States Air Force (USAF) and United States Army (USA) personnel from diverse functional backgrounds. The members are:

CPT Jason Bray, USA
CPT Michael Killaly, USA
Capt Woo-Suk Chun, USAF
Capt Tim Gannon, USAF
Capt Travis Johnson, USAF
Capt Dale Mull, USAF
Capt Jonathan Needham, USAF
Capt Mark Richey, USAF
Capt Krishna Surajbally, USAF
Capt Hans Winkler, USAF
Capt Stephen Woskov, USAF
1Lt David Ho, USAF
MSgt Carissa Parker, USAF
MSgt Christy Peterson, USAF
MSgt Jason Royals, USAF
TSgt Joseph Hicks, USAF

CENTER FOR SYSTEMS ENGINEERING (CSE)

In early 2002, Air Force Materiel Command (AFMC) identified gaps and shortfalls in the implementation of systems engineering (SE) throughout the Air Force acquisition process. Subsequently, AFMC made recommendations to improve and institutionalize SE concepts throughout the Air Force and DoD acquisition processes. The Secretary of the Air Force then provided oral direction in April 2002 for AFMC/CC (Air Force Materiel Commander) and AFIT/CC (Air Force Institute of Technology Commander) to establish the CSE, which would implement these recommendations.

In December 2003, AFMC/CC, AFSPC/CC (Air Force Space Command Commander), and AETC/CC (Air Education and Training Commander) signed a Memorandum of Agreement (MOA) establishing CSE as the Air Force SE focal point. This MOA defined the CSE's roles as: advocating for SE by documenting case studies, developing standards and tools, generating core guidance and policy recommendations; supporting collaboration across the Air Force and other services by capturing and making available current SE knowledge residing within each organization; providing consulting services on SE issues by assisting organizations in obtaining SE expertise; and providing/supporting SE education and training by leveraging resources from academia, industry, and professional organizations in order to tailor applications for Air Force needs.

Although CSE is embedded within AETC's chain-of-command, the MOA enables support from HQ (Head Quarters) AFMC/EN (Directorate of Engineering) as required. As such, CSE leverages HQ AFMC/EN's functional chain in order to establish a command-wide presence to accomplish their mission. HQ AFMC/EN oversees SE discipline at four of the five Air Force Product Centers: Aeronautical Systems Center (ASC), Electronic Systems Center (ESC), Nuclear Weapons Center (NWC), and Air Armament Center (AAC). Space and Missile Systems Center (SMC) is the fifth Product Center, organized under HQ AFSPC/A4A6 (Director of Logistics and Communications). HQ AFSPC/A4A6 is also MOA signatory, providing support to CSE as required. Outside of support available through HQ AFMC and HQ AFSPC, CSE may champion their efforts with assistance from the Assistant Secretary of the Air Force Directors for Acquisition Integration (SAF/AQX) and Science, Technology, and Engineering (SAF/AQR).

COLLABORATIVE EARLY SYSTEMS ENGINEERING

As CSE explored ways to advance the SE discipline across the Air Force, its investigation converged on improving materiel acquisition during early systems engineering (ESE) as a primary goal. ESE is the application of SE processes and products during early (pre-Milestone A) stages of the DoD acquisition process. This phase of materiel acquisition is known as Concept Exploration and Refinement, and is typically led by subject matter experts (SMEs) residing in each acquiring command's Capabilities Integration Directorate (XR) offices. For ESE guidance, SMEs may refer to the initial release of the Early Systems Engineering Guide (2009), which focuses on SE efforts necessary to produce the analysis of alternatives for a given capability requirement. Accordingly, each ESE process/product contributes to the eventual delivery of a system possessing capabilities that meet or exceed JCIDS (Joint Capabilities

Integration and Development System) requirements, whether the system is approved either as a new program start or legacy system modification/upgrade.

ESE processes/products include, but are not limited to: mission task decomposition, concept engineering, concepts of operations, Operational View 1 (OV-1), concept characterization and technical description (CCTD), capstone requirements documents, technical trade-space documentation, initial capabilities documents, developing initial requirements baselines, and work-breakdown structures. A centralized clearinghouse of data is vital to effective ESE execution. As such, the ESE Guide recommends that concept engineering teams create a repository and populate it with concept templates, background, specific definitions, analyses, evaluations, reports, educational materials, compliance documentation, security compliance criteria, etc. The repository should also be used to catalog concept engineering tools, while providing interfaces to outside organizations or specialized bodies of knowledge.

The ESE discipline holds significant potential to coordinate the SE components of early materiel acquisition, which boosts efficiencies necessary to rapidly field warfighter capabilities. While ESE will enable front-end reductions in materiel life-cycle costs, the game-changing value of ESE is rooted in the coordinated development of materiel solutions that meet requirements and interoperate to achieve synergistic effects. Hence, CSE is promoting collaboration among the Air Force product centers as a means of improving ESE, referred to as collaborative early systems engineering (CESE). CSE aims to drive CESE by working with the product centers to define new standards, tools, processes, guidance, and policy. CESE will immerse the Air Force product centers in a coordinated working environment, increasing the overall effectiveness of materiel solutions to warfighter requirements. Additionally, CESE will enhance inter-service materiel acquisition by promoting an open architecture for integrating SE practices among joint programs.

DEVELOPMENT PLANNING

Sound decisions regarding capabilities-based requirements are critical to materiel acquisition success in today’s environment of declining budgets and rapidly evolving threats. With that, decisions made prior to program initiation have tremendous impact on subsequent development and production costs, and opportunities to influence these factors rapidly diminishes as the acquisition process progresses. Many decisions are made with insufficient technical analysis and planning to sufficiently identify, assess, and inform senior Air Force leaders of the technical risks associated with acquiring a given materiel solution. The absence of early technical information may result in solution strategies that have not surveyed a sufficient spectrum of technical and joint mission area opportunities. Hence, programs may be initiated with poorly conceived requirements, inaccurate cost and schedule estimates, unknown and costly technical risks, deficient engineering/analysis to mitigate program risks, and lost opportunities to integrate solutions across the spectrum of weapon systems. Such decisions are unacceptable, and the Air Force is committed to recapturing acquisition excellence.

The Weapon Systems Acquisition Reform Act of 2009 (WSARA) requires DoD to develop policies and guidance for the acquisition workforce responsible for SE and Development Planning (DP). Therefore, WSARA provides the impetus for reinvigorating DP among the services. In short, the objective of DP is to ensure high confidence programs that deliver weapon systems with appropriate capabilities, on time, and on cost. DP is not a separate phase of acquisition, but rather a suite of best practices and processes to ensure successful early acquisition planning. DP provides integrated assessments of performance, cost, and risk to enable competent investment decisions regarding concepts (prospective materiel solutions) to meet identified operational capability requirements. Rigorous SE processes are key to the success of this endeavor.

In fact, DP emphasizes pre-Milestone A application of ESE's best practices in order to meet materiel requirements. As such, DP is designed to promptly execute ESE processes that accurately define the relevant technical elements of each concept. However, DP's efficacy hinges on concept characterizations and technical descriptions (CCTD) as enduring products of ESE, which capture the analytical basis of the concepts (prospective materiel solutions) and associated technologies necessary to address materiel requirements.

In 2010, AFMC/CV (Air Force Materiel Command Vice Commander) and APSPC/CV (Air Force Space Command Vice Commander) signed a DP Governance Charter which established the organizational structure, purpose, and operating procedures for Working Group, Board, and Council forums. This Governance Structure evaluates, integrates and manages Air Force materiel DP efforts. The DP Working Group serves as an advisory and execution body to the DP Board and Council to ensure optimum materiel options in response to Air Force shortfalls and gaps.

REPORTS

Recent investigations by AFMC and AFIT have identified areas in the DoD acquisition process requiring more CESE among the stakeholders. In 2010, an AFIT team investigated the need for CESE at the Air Force product centers. The report identified current implementations of CESE within centers, but also identified a lack of collaboration among the centers themselves. Common tools, nomenclature, understandings, and processes to support CESE are not present due to this lack of communication. Recently, a team of AFIT researchers looked at knowledge management (KM) within and among the Air Force product centers with the 2010 report in mind. The team recommended KM assessments, identifying various knowledge types in the organizations, and implementing a knowledge repository system.

STRATEGIC INFORMATION MANAGEMENT LENS

The approach toward improving CESE can be viewed from a number of different perspectives. In this report, the team analyzed the problem from a Strategic Information Management (SIM) perspective. SIM is based on the concept that good strategic information underlies good strategic decisions, and that having good strategic information does not simply happen. It must be planned for, gathered, interpreted, organized, integrated, stored, updated, and made available for dissemination as needed for strategic decisions. For all of this to happen, there must be a conscious focus on organizational goals, customer needs, and common understanding across the enterprise. There must be knowledge of what strategic decisions are to be made and what information is necessary to support those decisions.

Galliers (2009) conceptualized SIM in four concentric rings as shown in Figure 1. Information systems (IS) strategy, the core of SIM, is comprised of four interrelated strategies: information, information management, information technology and change management strategies. Technology becomes more powerful with each passing day and is increasingly available at a low to modest cost. Some would argue that technology no longer provides a distinguishing competitive edge. Instead, the strategy to utilize that technology provides the competitive edge distinction. The focus should be on *people's creative use of the technology systems rather than the technology itself* (Dearstyne, 2002).

Figure 1. Conceptualization of SIM

SIM continues to be a critical issue in the twenty-first century, as society grows reliant on information and communication technology. Sound SIM provides organizations with "…flexibility, responsiveness to change and ability to respond to new challenges (Dearstyne, 2004)." Organization success becomes dependent on an organization's ability to effectively and efficiently utilize IT within the firm (Galliers & Leidner 2009).

2. The Air Force Product Centers

Current Strategic Information Management in Product Centers

A key focus for CSE is the smart design of processes that guide acquisition business practices and product development. Currently, the product centers operate with unique and mostly uncoordinated efforts. In review of "An Investigation of Air Force Product Center Needs for Supporting of Collaborative Early Systems Engineering," the recent efforts of CESE are important to discuss in the context of SIM.

Product centers are continually in the process of optimizing for their own business priorities, which creates friction points when endeavors for holistic systems engineering attempt integration. Perhaps a major reason why this occurs is because of the unique cultures of the centers. Unique cultures result from the different products, quantities, costs per product, cycle times, manufacturing tolerances, number of customers, interface requirements, and overall tolerance for risk for each product center. Table 1 below shows a general comparison of two product centers as reviewed by Mr. Richard Freeman (Technical Director, CSE). Air Armaments Command (AAC) and Space and Missile Command (SMC) are two of the most dissimilar product centers and provide a good example of the unique challenges faced by each. The table reveals a large relative difference in a number of categories. The nature of the work and associated cultural environment is noteworthy.

	AAC	SMC
Products	Weapons	Space Vehicles
Quantity	Many	Each
Cost per Product	↓ (<$1M)	↑ (>$1B)
Cycle Time	Short (1-3 yrs)	Long (5-20 yrs)
Manufacturing Tolerance	↓	↑ (Higher sensitivity)
Number of Customers	Many	Few
Interface Requirements	Many	Few
Tolerance for Risk	↑	↓↓↓

Table 1. Product Center Relative Comparison: AAC & SMC (Freeman 2010)

A consideration of the differences identified in Table 1 between AAC and SMC suggests some of the reasons why they have developed different approaches and cultures. AAC develops weapons that are often purchased in large lots over time, and that are relatively inexpensive, compared to SMC's efforts. SMC, on the other hand, undertakes relatively few space shots that may be in development for decades, and are more expensive by orders of magnitude. As a result, SMC is likely to be much more risk averse than AAC. With a higher risk aversion, SMC routinely engages in more conservative practices with redundant desk drills and formal checklists. On the other hand, AAC's lack of dependence on a single launch of a missile that costs billions of dollars, leads to a culture that is not as highly risk averse, leading to more tolerance for cross center interchanges and more dynamic standard enforcement practices (Freeman 2010). Some of the product centers may have more in common than AAC and SMC. Regardless, different cultures are present. All of the nuances and unique pressures of each product center encourages divergence. This cultural friction appears to be a major source of resistance to collaboration and sharing information.

Even so, the product centers have the opportunity to make a significant contribution to better information management. By employing the philosophy and services of CESE along with new IT capabilities in a more strategic format, a migration in SIM architecture is possible.

THE ROLE OF DEVELOPMENT PLANNING WORKING GROUP

Recently, attempts of progressing CESE have been made through the Development Planning Working Group (DPWG). According to the USAF Material Commands' Development Planning Governance Charter dated 26 Jan 2010, the mission of the DPWG is to "recommend prioritization of Air Force DP efforts to the DP Board and conduct quarterly vetting, integrating, and statusing of the DP activities that are executed by AFMC and AFSPC Material Centers." Additionally, the responsibilities of the DPWG involve:

- Providing centralized integration of Material Center DP support
- Assisting in the identification and assessment of horizontal integration or cross-cutting opportunities
- Identifying and recommending the use of standard, consistent tools

The activity and efforts of the DPWG over the past year (Oct 09 to present) was reviewed from documents available through the AFMC/AFSPC Development Planning CoP (Community of Practice) on AFKN (Air Force Knowledge Now). Activity found to be relevant to integration and collaboration included:

- Oct 2009 DP Strategic Workshop:
  1. Attendees discussed and agreed upon the definitions of common DP terms
  2. "Collaborative Development Centers" was mentioned as a "Future Path Ahead" in the SAF/AQR Vision of DP briefing

- Apr 2010 O-6 Working Group:
  1. A Cross-Center Integration briefing was conducted by Ms. Terri Dorpinghaus, HQ AFSPC/A5X. The briefing identified "Integration Teammates," representing each of the 5 AF Product Centers and HQ AFMC/A5C; it discussed the purpose of the integration effort, what work the team had already accomplished, and future integration topics; and how leadership would be involved (namely the O-6 WG).

- Aug 2010 DPWG:
  1. A Proposal for a CESE Environment briefing was presented by Col John Paschall, Acting CSE Director. This briefing provided the problem statement, phased CESE development, and the proposed way ahead.

The CSE-AFIT team, which conducted an investigation of Air Force Product Center needs in early 2010, stated that they believed DP to be an ideal launch pad for CESE. Though the observations of past DPWG involvement in ESE integration/collaboration issues were not plentiful, there is evidence that these ideas are not new. The recent CESE proposal may serve as a catalyst for bringing such issues to the forefront of the DPWG. Overall, continuous and consistent focus on CESE will be needed in the DPWG if progress is expected.

EARLY SYSTEMS ENGINEERING CONCEPTS

An organization's reason for existence is conveyed through its mission statement. The CSE's *mission is to* "develop new SE concepts that will provide processes, practices, tools and resources to the SE workforce through research, education, and consultation for air, space and cyberspace competence." In accordance with this mission, CSE has produced a guidebook for ESE. This guidebook underscores concepts of how SE can assimilate acquisition efforts.

As referenced in the ESE Guidebook, the 2006 Defense Acquisition Performance Assessment (DAPA) Project Report Survey results showed that requirements instability was the most mentioned problem area, followed by funding instability and technology maturity. To minimize costly and time-consuming changes during development process, requirements must be expressed with completeness and accuracy. These requirements must be assessed and balanced with respect to parameters such as effectiveness, cost, schedule, risk, and evolutionary potential; this is a key element of the Analysis of Alternatives (AoA) that selects a Preferred System Concept (PSC). SE collects, coordinates, and ensures traceability of all stakeholder needs into a set of system requirements through a balanced process that takes into account effectiveness, performance, cost, schedule, and risk. Also early SE provides an audit trail from the users' capability gaps and needs. Early SE can be divided into four segments:

- Capabilities-Based Assessment (CBA)
- Concept Exploration and Refinement (CER)
- Preferred System Concept (PSC) maturation
- Technology Development (TD)

CBA develops potential material and non-material concepts to address capability gaps and shortfalls, or to exploit new capabilities provided by new technologies. CER provides for developing material solutions to warfighter shortfalls and refining the activities at the front end of the acquisition life cycles. CER is intended to enhance the quality and fidelity of proposed future military system concepts. Each concept developed under CER will have been technically researched, analyzed, and evaluated against a validated set of mission-based requirements and costs for the entire life cycle. The concept engineering team is responsible for creating and delivering all documentation and executing all control milestones and reviews.

Post-AoA phase is where the PSC is matured into a stable, producible, testable, supportable, and affordable program. PSC maturation efforts are characterized by the planning necessary to ensure a high confidence of program success. Post-AoA must include all activities necessary to successfully complete the TD phase. Key TD efforts include:

- Exploring the feasibility of the operational requirements and maturing the initial capability document into a final capability document
- Mitigating risks to the level necessary to support a favorable milestone B decision
- Developing a preliminary design of PSC that is feasible, affordable, and will meet operational requirements
- Determining the affordability and military utility of the preliminary design before committing to full system development

Risk management is the heart of technical and SE planning during Post-AoA phase and a critical first step toward affordable, manageable, and executable TD phase efforts.

INTEGRATION OF SYSTEMS ENGINEERING INTO THE PRODUCT CENTERS

A major SE dilemma in addressing problems in a complicated system is how to actually integrate the concept of SE. Integrating the SE solution involves boundary clarification. The product, enterprise, and service view model of integration presented below in Figure 2 shows how current endeavors are intended to impact different boundaries at once (Freeman, 2010).

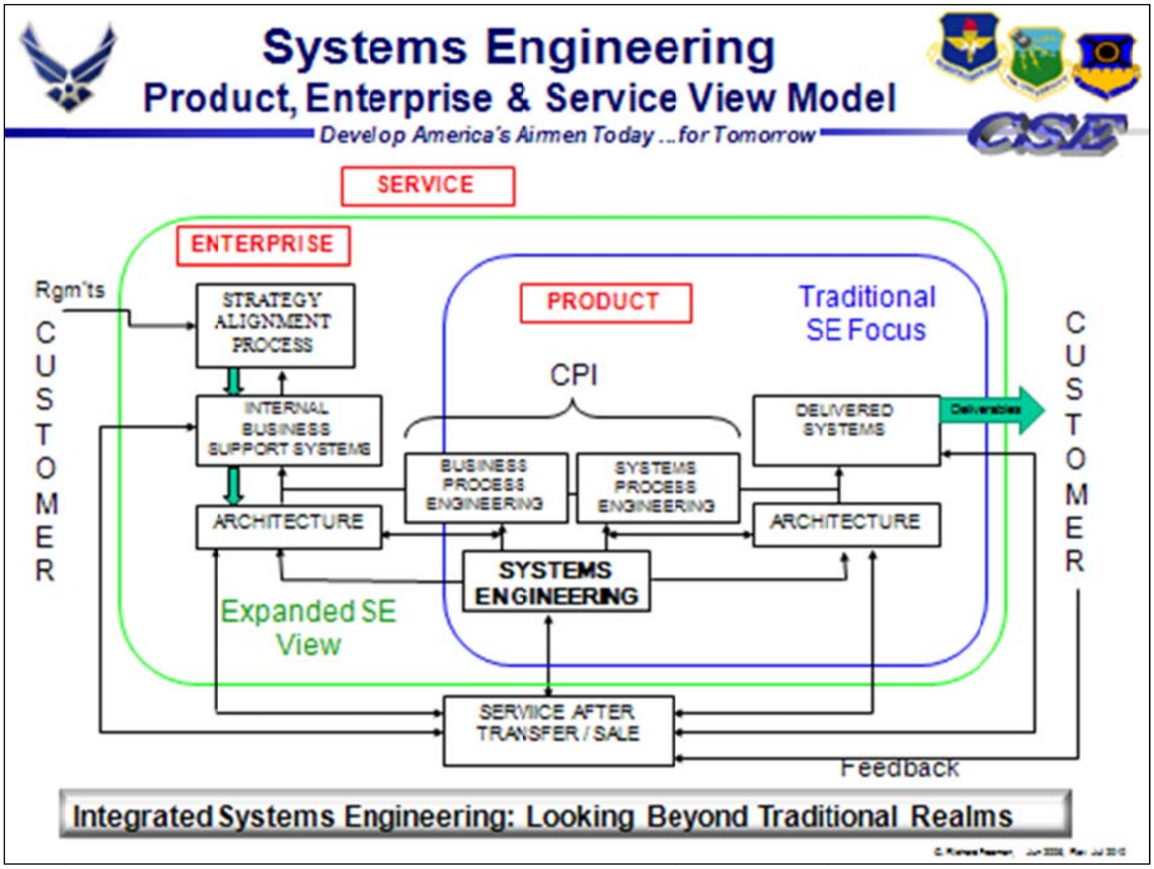

Figure 2. System Engineering Integration Slide

Systems engineering can provide the integration of business processes and systems processes, based on support for an enterprise architecture that extends not only across the traditional SE focus, but across the enterprise as well. It also provides a vehicle for integrating the needs of the customer: at requirements gathering, product delivery, and service after delivery.

Overall, today's poor status of strategic management of information across the product centers validates the need for SE. SE maintains a holistic approach that will only be effective if incorporated into the congruent efforts of the DPWG. Continued emphasis on utilizing the existing guidebook on ESE will also help establish a foundation for future use. A consideration of how SIM can accentuate the SE efforts from an "operating model" and a "stages of enterprise architecture" perspective is provided in the following sections.

3. An Operating Model View of Support for CESE

One of the roles for CSE, as designated in the 2003 MOA, is to provide a means for collaborative SE work efforts across the Air Force, among the Armed Services and DoD. A 2010 report investigating the Air Force Product Center Needs for Support of CESE recommends that the CSE become the vehicle for breaking down the isolation among the centers and for fostering collaboration across all aspects of systems engineering with a focus on ESE.

Weill (2008) developed an organizational operating model based on high and low business process standardization and integration (Figure 3). Low business process standardization and low business process integration results in a diversification operating model, in which each organizational unit operates largely independently. It focuses on optimizing each separate unit independently of the others. The operating units are seen as having little in common with each other.

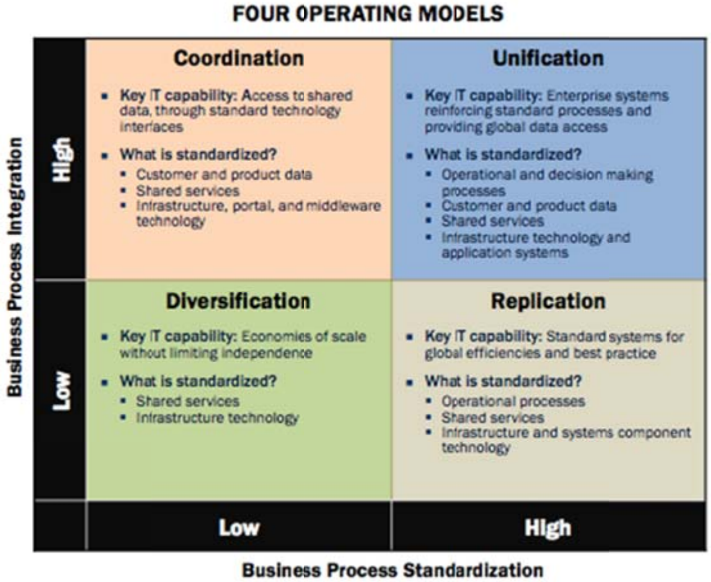

Figure 3: Focus of Standardization by model (*Weill,* 2008)

With high business process standardization and low business process integration, a replication model results, in which each operational unit performs similarly to the other units. Individual differences are minimized. However the work of the various units is not designed for integration of effort.

With high business process standardization and high business process integration, a unification model results, in which the business units operate similar to each other. They share data and respond to common customers. This model focuses on supporting units that operate similarly for common customers.

High business process integration and low business process standardization results in a coordination operating model. In this model, while the business processes are similar and information is shared, differences in process standardization allow for differences in the needs of the individual units.

The establishment of a clear operating model is an organizational commitment to a new way of doing business. The selection of an operating model is a critical decision because it forms the foundation for decision making, how to strategically position the organization, and which capabilities to develop and leverage. It guides the development of business and IT capabilities and drives the strategy and vision of the company. According to Ross et al. (2006) companies that have defined an organizational operating model have reported 31% higher operational efficiency over those that don’t

The Air Force Product Centers currently perform development planning with specialized tools that are specific to each center. This leads to a lack of commonality across the centers, not only in their tools, but standards, nomenclatures and processes. The lack of commonality means that the Air Force Product Centers are currently working as diversified entities within AFMC and AFSPC.

The diversification operating model is a decentralized organizational design that works best to support different products and services and benefits from local autonomy in deciding how to address customer demands (Weill, 2005). The diversification operating model is characterized by having low business process integration and low business process standardization. While this model can work well in a situation where individual products are independent of each other, DoD is finding that more and more, there is a need for information sharability and system interoperability. The Air Force Product Centers have independent transactions and operate as unique entities. They have few data standards across the centers and most IT decisions are made at the center level. The centers have control over their process design, as long as they follow DP and ESE guidelines. Entities using the diversified model encourage local growth of the individual entity.

Based on the current DoD acquisition strategies to capitalize on information sharing and weapon system interoperability, there is a need for the business units (product centers) to make accurate and timely information available to other business units (product centers) so that system interoperability can be designed into future weapon systems. Since the DoD acquisition model is a common model for all weapon system development, and because of the desire to promote communication and understanding across the product centers, there would be value in having them run their business operations in the same way. From this, one can conclude that the coordination operating model would be preferable. It allows for information sharing across the enterprise, while also supporting the individual differences of the product centers.

This is particularly true since much of the terminology and language is tied to specific phases and operations within the acquisition lifecycle. As an example of how even simple common understandings can be difficult to achieve, consider a workshop sponsored by CSE in summer 2009. Representatives from the Air Force product centers, along with AF XR organizations spent an hour striving to come to common agreement on the meaning of the word "concept", as used in the term "concept development". After an hour's discussion, the group was able to create a common definition that they would only agree to for the length of the current workshop. If something as fundamental as the definition of "concept" eluded the group for long term understanding, one can easily imagine the difficulty that the various actors in the acquisition process will have

COORDINATION OPERATING MODEL

Unlike the diversification operating model, coordination calls for high levels of integration while allowing low levels of process standardization. Business units operating in a coordination company tend to share one or more of the following entities: customers, products, suppliers, and partners. With coordination, key business processes are often integrated, however, the lower level business units of the company may have unique operational functions with unique capabilities. Ross et al. (2006) characterizes coordination by the following attributes:

- Shared customers, products, or suppliers
- Impact on other business units transactions
- Operationally unique business units or functions
- Autonomous business management
- Business unit control over business process design
- Shared customer/supplier/product data
- Consensus processes for designing IT infrastructure services; IT application decisions made in business units

For companies with a coordination model, independent business heads execute their processes in the most efficient manner possible, but corporate directives and negotiations focus on providing the best service to the customer. Successful companies rely on incentive systems and management training to encourage companywide thinking at the business unit level (Ross et al., 2006). By integrating, but not standardizing business functions, the coordination operating model allows companies to foster expertise within the business and increase customer service simultaneously.   A coordination core diagram is shown in Figure 7.

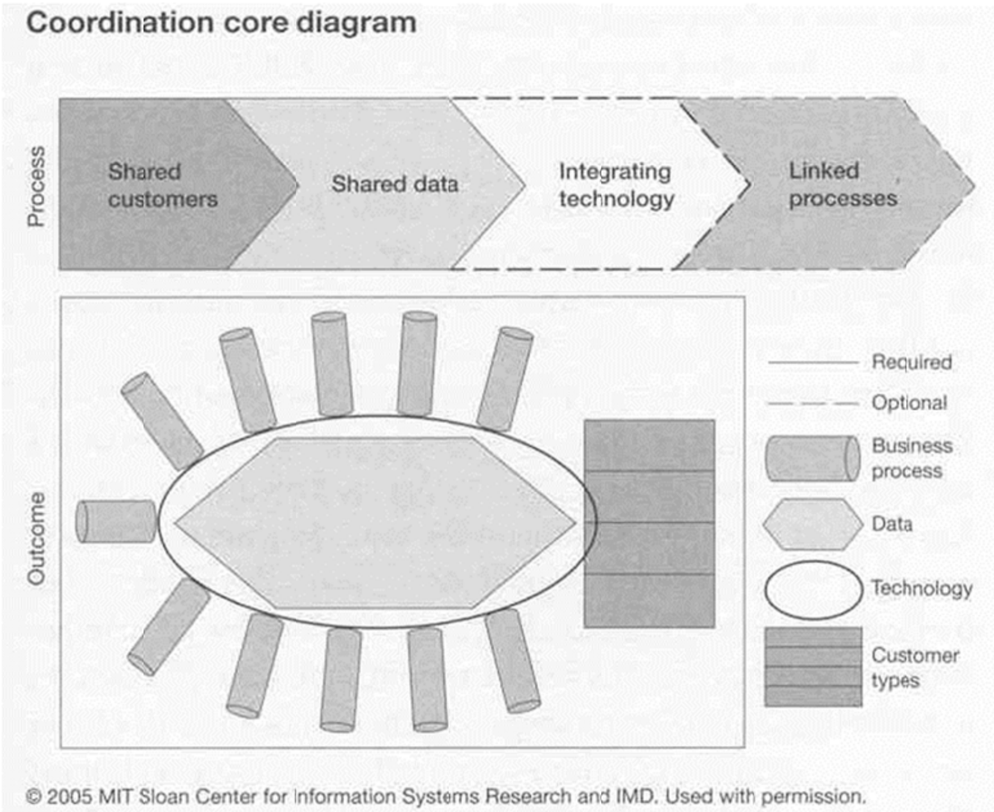

Figure 7. *Source*: Derived from Ross, 2006

4. Stages of Enterprise Architecture Maturity:

The CESE approach can be strengthened if the centers have a common architecture to begin the development of common standards, nomenclature, tools, processes and systems. "Enterprise architecture (EA) initiatives can involve dismantling legacy systems or redesigning business processes" (Ross, 2005). Each of the product centers currently have tools that are specific to their center, they perform different tasks and implement the DP process in different phases. In order to improve collaboration efforts among all centers, a clear idea of their IT status is necessary. Maturity models can be used to support an as-is analysis, to derive, and prioritize improvement measures for the products centers.

"Maturity models are grounded in the concept of process improvement and are derived from stage theories which are based on the belief that systems, processes, practices, activities, and even enterprises themselves, can and do go through distinct stages over time" (Kappelman, 2010). According to Kappelman (2010), maturity models include a set of specifically described stages, occurring in a given sequence, a list of aspects or conditions for changing or evolving from one stage to another and a list of aspects or conditions that must be present in order for the transition to another stage to have occurred and be identified as having occurred. Maturity models can be considered as evaluative and comparative instruments to help improve collaborative endeavors across all the centers.

MIT's (Massachusetts Institute of Technology) Center for Information Systems Research (CISR) developed an architecture maturity model with four stages of enterprise architecture. These are business silos, standardized technology, optimized core, and business modularity (Table 2). Both the business units and IT must pass through these stages to move toward enterprise architecture maturity (Ross et al., 2006). Table 3 shows the characteristics of each stage from several perspectives. CSE should facilitate the product centers to move their enterprises forward incrementally, building buy-in and collaboration. An assessment of the product centers maturity level can help CSE understand where the centers have come from and what direction the centers should be headed.

Business Silos	Standardized Technology	Optimized Core	Business Modularity
IT applications serving local business needs	Clearly articulated technical platforms limiting choices and increasing efficiency	Standard data or processes increasing organizational discipline	Business process modules plug and play enabling business agility

Table 2: Architecture Stages Definitions (Derived from Ross, 2005)

The product centers are currently operating in Stage 1, business silos architecture. Stage 1 is where "companies look to maximize individual business unit needs or functional needs" (Ross et al., 2006). At this maturity level, each product center has developed its own methods, communicates in its own language and appears only interested in moving its center along. Over time, CSE can measure the maturity of EA in each center to indentify strengths, areas of improvement, and subsequent activities to effect improvement in the processes and practices across the centers. Once each product center is assessed, CSE can set a course of action to advance the centers to the next stage of maturity. Stages cannot be skipped, because each stage is dependent on the capabilities provided by the previous stage for its implementation. The next three stages of the maturity model can help move the product centers toward reasonable plans in developing a collaborative effort with CSE advocacy for integration and standardization.

	Stage 1 Business Silos	**Stage 2 Standardized Technology**	**Stage 3 Optimized Core**	**Stage 4 Business Modularity**
IT Capability	Local IT applications	Standard technology platforms	Enterprise-wide standardized processes or data	Plug-and-play business process modules
Business Objectives	ROI of local business initiatives	Reduced IT costs	Cost and quality of business operations	Speed to market; strategic agility

Funding Priorities	Individual applications	Shared infrastructure services	Enterprise applications	Reusable business processes
Key Management Capability	Technology-enabled change management	Design & update of standards; funding shared services	Core enterprise process definition & measurement	Core enterprise process definition & measurement
Who Defines Applications	Local business leaders	IT and business unit leaders	Senior managers and process leaders	IT, business and industry leaders
Key IT Governance Issues	Measuring and communicating value	Establishing local vs. regional vs. global responsibilities	Aligning project priorities with architecture objectives	Defining, sourcing and funding business modules
Strategic Implications	Local/functional Optimization	IT efficiency	Business operational efficiency	Strategic agility

Table 3: Stages of Enterprise Architecture Maturity (MIT Sloan CISR, 2005)

In Stage 2, Standardized Technology, CSE can facilitate technology standards intended to decrease the number of platforms that are managed across all the centers. This stage establishes platform standardization, such as standard hardware, operating systems, languages and database management system products. CSE, along with the product centers, can negotiate standardize technology to reduce the number of products performing similar functions among the centers. This evolution positions the products center to be able to identify which processes should be local to their center and which should be standard across all the centers.

As the product centers migrate through each stage, the shift from local optimization to enterprise optimization begins to occur. In the Optimized Core stage, companies move from a local view of data and applications to an enterprise view (Ross et al, 2006). Stage 3 involves major new enterprise system implementations and transformation change. At this stage, the product center can begin to benefit from data sharing and process standardization to facilitate achieving CESE.

According to Ross (2005), data and process standardization when combined with integrating technologies generate greater sharing and integrated process standards. CSE can use the architecture maturity stages to help the product centers build out their EA to achieve a desired level of integration and standardization across all centers. In the final the stage, business modularity, the architecture is able to provide seamless linkages between business process modules. “With a solid platform of core processes, data and technology, a company can plug and play business modules on either level, and modular interfaces make changes simpler to implement” (Ross, 2006). Stage 4 of the EA maturity model supports the DoD Net-Centric Vision to provide an information sharing environment among the product centers.

NET CENTRICITY

One part of the DoD Net-Centric Vision is to function as one unified DoD Enterprise, creating an information advantage for our people and mission partners by providing a rich information sharing environment in which data and services are visible, accessible, understandable, and trusted across the enterprise.

Improving the Department's ability to share information helps realize the power of information as a strategic asset. Sharing benefits include: achieving unity of effort across mission, improving the speed and execution of decisions, achieving rapid adaptability across mission and coalition operations, and improving the ability to anticipate events and resource needs, providing an initial situational advantage and setting the conditions for success (Department, 2007). The goals are to achieve an information sharing environment across organizations to promote, encourage, and incentivize sharing and achieve an extended enterprise.

The DoD Net-Centric Data Strategy attributes include ensuring data are visible, available, and usable when and where needed to accelerate decision making (Department, 2003). Newly designed and real-time systems can offer services that work in the background collecting real-time data, storing it, and providing access and discovery through an enterprise interface that is available to all centers. In the Scope of the Net-Centric Data Strategy, the shared service is a discoverable repository that houses the visible and available data for product centers.

CASE STUDY: METLIFE ADOPTS COORDINATION OPERATING MODEL

MetLife is a large enterprise that provides insurance and financial services to both individuals and institutions and is considered a gleaming example of a large enterprise that has successfully implemented the coordination model (Ross et al., 2006). Like our Air Force acquisition centers, MetLife has implemented systems across their operations that facilitate a large set of diverse and specialized processes. Yet, as Ross et al. (2006) explain, the "individual products and product lines required specialized knowledge, thereby limiting opportunities for standardization across products and business units" (p. 58).

In order to accommodate successful coordination, MetLife recognized the importance of integrated data and implemented the use of portals to allow groups to share entry to the hub. The EA core diagram in Figure 8 illustrates how they managed to accomplish this. Coordination is achieved by linking the application tier with the logic and data tier through the use of portals accessing an integration hub – allowing a strategic information management approach that focuses on sharing data.

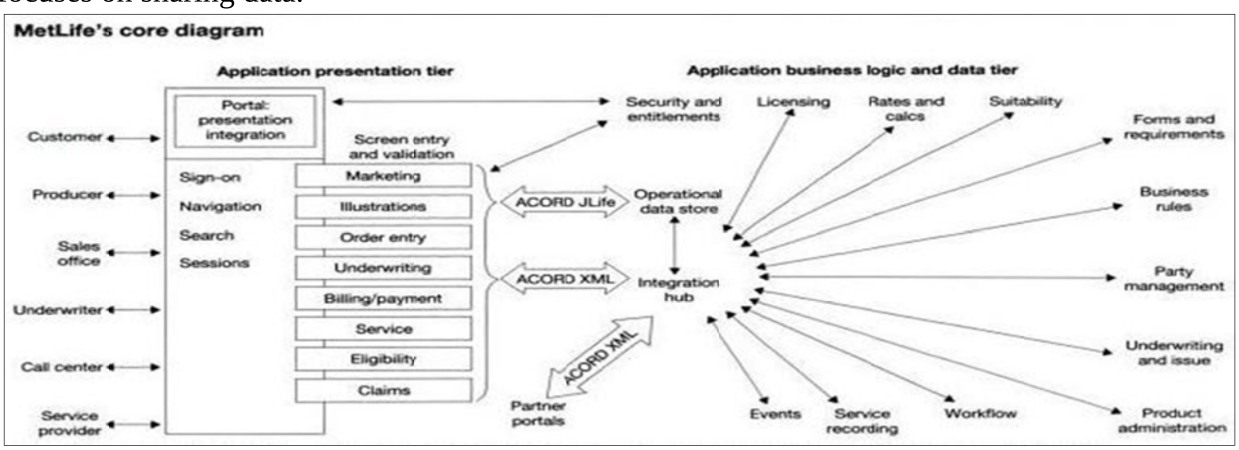

Figure 8. *Source*: Derived from Ross et al., 2006

CASE STUDY: MERRILL LYNCH ADOPTS COORDINATION OPERATING MODEL

Merrill Lynch and its Global Private Client (GPC) business provide another example of the coordination operating model. Merrill Lynch offers a wide variety of financial products, from credit cards to loans to investing. GPC has over 14,000 financial advisors providing these products at approximately 630 international offices. Merrill Lynch also provides customers multiple ways to remotely interact with their financial services, including websites and call centers. Each product line, regional office, and customer communication channel operates differently from the next due to the nature of the product, the needs of the customers in a certain region, or the way a channel interacts with a customer. But they all need to work together to provide the customer a seamless experience. Merrill Lynch facilitates this through what it calls the Total Merrill platform. This platform integrates access to products across customer bases and integrates access to customer data across products and channels. Despite each customer, product, and channel requiring and producing different sets of data, they all share data on the same network and can quickly and easily pull data from each other. Also, data that is required for multiple uses comes from a common source, eliminating redundant and conflicting data. Each product line accesses the same real time information to identify the customer and the current products he or she owns. And a customer can interact with Merrill Lynch through any of the provided avenues and access the same products and information (Ross et al., 2006).

5. Findings and Recommendations

FINDINGS

Although, current DoD strategy recognizes the value of information sharing and system interoperability as an essential capability of new weapon systems, the processes by which weapon systems are developed are stand-alone, non-information sharing efforts.

The team determined the following findings:

1. The Air Force Product Centers appear to be operating in Weill's diversification operating model. Characteristics of this model include low business process standardization and low business process integration. There are a number of characteristics that the product centers display that support this conclusion. Among those characteristics we found the following:
    a. Each center has a unique culture
    f. Each center has a specific mission with distinct functional requirements
    g. Each center works with different contractors and customers
    h. Each center uses different business processes, standards, and technology
    i. Each center is geographically separated from the others
    j. Each center has a different organizational structure

2. From the standpoint of enterprise architecture (EA) the product centers are in the business silo stage. At this stage, each center's information stores and tools serves its own local needs. Sharing across centers is not a realistic option at this stage.

3. CSE initiated participation in the Development Planning working group; however, its involvement is still early.

4. CSE has initiated working groups.

RECOMMENDATIONS

The following recommendations are made in response to the findings:

1. The product centers should consider moving toward a Coordination Operating Model.

A coordination operating model would better support the DoD strategy of information sharing and development of interoperable weapon systems. Such a model would provide the coordination among the product centers while still supporting the ability of each center to support the needs of its own types of products, and its own customers.

2. The product centers should consider the stage of their enterprise architecture, with a goal of moving from stage 1, the Business Silo stage to stage three, Optimized Core, or stage four, Business Modularity to support the need to develop interoperable weapon systems.

Moving beyond the Business Silos stage of enterprise architecture is a necessary requirement for providing the necessary infrastructure to support the desired level of information sharing and the development of interoperable weapon systems.

3. The Center for Systems Engineering (CSE) should become the vehicle for coordinating the effort to move the product centers toward a coordination operating model and an enhanced enterprise architecture stage.

CSE should become the vehicle for breaking down the isolation among the centers and for fostering integration across all aspects of SE with a focus on ESE. CSE may consider becoming a system of systems through a strategic move toward a Coordination EA model. CSE has established a system of systems integration working group with the following objectives: 1) Address continued enterprise interoperability and integration, 2) Communicate proposed configuration (technical baseline) changes within and across Centers and in turn to all possibly affected dependent programs, 3) Ensure impacts to all programs are reported at Configuration Steering Boards (CSBs), and 4) Drive interoperability and integration focus into AF Program Support (PSR) process.

4. CSE may consider working with the product centers to establish a plan with scheduled milestones for moving toward compliance with the new DoD policy/guidance regarding information sharing and interoperability.

As it currently stands, there appears to be no leadership or governance guiding this process. As a result, the centers seem to lack motivation to make changes. The CSE can fill this leadership gap and become the catalyst for the move to DoD interoperability and information sharing. The lack of interoperability among entities becomes apparent when there are high profile operation failures. Past efforts at achieving interoperability have resulted in organizations use of translator functions to communicate on a case-by-case basis. This Information Exchange Requirement (IER) communication focuses only on the information that may seem to be important by the affected entities and is based on the organizations' operating protocols. This method of information exchange is difficult and costly. The emphasis of IER does not consider that information needs to be widely shared to be of most benefit. The legacy thinking that interoperability jointness must only be at the operational level creates a blind spot due to the lack of peer-to-peer communication at the tactical level. As new capabilities and new entities are deployed, IER becomes an obstacle to interoperability by making it difficult to allow the widespread sharing of information needed for net-work centric operations (Alberts & Hayes, 2003).

5. CSE may consider furthering their involvement in the Product Center working groups.

Continued or expanded use of these forums show promise of producing integration solutions that work for all parties involved. Most importantly, if the centers can collaborate and make their own changes, rather than have changes forced upon them, the ownership they feel for the solutions will greatly increase the likelihood of successful implementation.

6. Conclusions

Each Product Center has its own way of doing business. As a result, these diverse methods have developed unique cultures within each Center. However, it is *not* feasible to change the entire culture of each Center, certainly not in the short term; only the mindset that one specific methodology is the "right" way to do business. After all, each Center has been operating independent of the others for years and has experienced success doing so. However, in order to stay on the cutting edge, and develop the interoperable weapon systems demanded by the DoD, the Centers *must* share information much more broadly and do it efficiently. Acting independently only creates interoperability problems in a finished product. This type of problem is clearly seen in the F-22 and F-35. These two aircraft, the most modern aircraft in our inventory, were developed with overlap in time, yet their information systems do not talk to each other. Only through a retrofit will these airframes be able to share information at the level required in today's and tomorrow's operating environments. Situations like this simply cannot be allowed to happen moving forward. Solutions to this problem depend on a growing ability for the product centers to share information and cooperate in the development of future weapons systems. Approaches presented in this paper point the way to possible approaches that will move our acquisition processes toward a more collaborative environment, where we can develop and field the weapon systems that our nation will require in the years to come.

Glossary of Terms

AAC	Air Armament Center
AETC	Air Education and Training Command
AETC/CC	Air Education and Training Command Commander
AFIT	Air Force Institute of Technology
AFIT/CC	Air Force Institute of Technology Commander
AFMC	Air Force Materiel Command
AFMC/CC	Air Force Materiel Command Commander
AFMC/CV	Air Force Materiel Command Vice Commander
AoA	Analysis of Alternatives
HQ AFMC/EN	Directorate of Engineering
AFSPC	Air Force Space Command
AFSPC/A4A6	Director of Logistics and Communications
HQ AFSPC/A5X	Policy and Integration Division
HQ AFMC/A5C	Capability and Requirements Planning Division
AFSPC/CC	Air Force Space Command Commander
AFSPC/CV	Air Force Space Command Vice Commander
ASC	Aeronautical Systems Center
CBA	Capabilities -Based Assessment
CCTD	Concept Characterization and Technical Description
CER	Concept Exploration and Refinement
CISR	Center for Information Systems Research
CSE	Center for Systems Engineering
CESE	Collaborative Early Systems Engineering
DAPA	Defense Acquisition Performance Assessment
DP	Development Planning
DPWG	Development Planning Working Group
DoD	Department of Defense
EA	Enterprise Architecture
ESC	Electronic Systems Center
ESE	Early Systems Engineering
GPC	Global Private Client
HQ	Head Quarters
IER	Information Exchange Requirement
IS	Information Systems
IT	Information Technology
JCIDS	Joint Capabilities Integration and Development System
KM	Knowledge Management

MIT	Massachusetts Institute of Technology
MOA	Memorandum of Agreement
NCW	Network-Centric Warfare
NWC	Nuclear Weapons Center
PSC	Preferred System Concept
SAF/AQX	Assistance Secretary of the Air Force Director for Acquisition Integration
SAF/AQR	Assistance Secretary of the Air Force Director for Science, Technology, and Engineering
SE	Systems Engineering
SIM	Strategic Information Management
SMC	Space and Missile Systems Center
TD	Technology Development
USA	United States Army
USAF	United States Air Force
WSARA	Weapon Systems Reform Act
XR	Capabilities Integration Directorate

REFERENCES

Alberts, David S. and Hayes Richard E. *Power to the Edge.* Washington: DoD Command and Control Research Program, 2003

Bruce W Dearstyne. "Strategic Information Management: Continuing Need, Continuing Opportunities. " *Information Management Journal* 38.2 (2004): 28-35. ABI/INFORM Research, ProQuest. Web. 25 Aug. 2010.

Department of Defense. *Information Sharing Strategy.* Washington: DoD Chief Information Officer, 4 May 2007

Department of Defense. *Net-Centric Data Strategy.* Washington: DoD Chief Information Officer, 9 May 2003

Freeman, Richard G. Class Lecture: Product Center Comparison and Cultural Differences, 31 Aug 2010.

Freeman, Richard G. *Systems Engineering Product Enterprise View Model.* June 2006, Revised 19 July 2010.

Galliers, Robert D., and Dorothy E. Leidner. *Strategic Information Management*. Fourth ed. New York: Routledge, 2009.

Kappelman, Leon A. *The SIM Guide to Enterprise Architecture.* Florida: CRC Press, 2010

Ross, Jeanne W. "Understanding the Benefits of Enterprise Architecture," *Center for Information System Research*, Vol. V, No. 2B (July 2005)

Ross, Jeanne W. and others. *Enterprise Architecture as Strategy.* Massachusetts: Harvard Business School Publishing, 2006

Strouble, Dennis, Alan Heminger, William O'Connor, and Joseph Robb Wirthlin. *An Investigation of Air Force Product Center Needs for Support of Collaborative Early Systems Engineering.* 2010.

United States Air Force. *Early Systems Engineering Guidebook.* Assistant Secretary of the Air Force for Acquisition (SAF/AQ). Wright Patterson Air Force Base, OH: 2008.

USAF Materiel Commands. Development Planning Governance Charter, 26 Jan 2010.

Weill, Peter and Ross, Jeanne W. *Implementing Your Operating Model via IT Governance,* Sloan School of Management, Center for Systems Information Research, Volume VIII, March, 2008.

Weill, Peter and Ross, Jeanne W. *Forget Strategy: Focus IT on Your Operating Model,* Sloan School of Management, Center for Systems Information Research, Volume V, December 2005.

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14. ABSTRACT DoD strategy highlights the need for information sharing and system interoperability. U.S. Air Force weapons systems are conceptualized and delivered by the USAF product centers (PC). This report examines the product centers and provides a roadmap for future integration. Findings: (1) The PC are operating in Weill's diversification operating model. Characteristics of this model include low business process standardization and integration. PCs have unique culture and mission. They work with different contractors and customers, using different processes, standards, and technology. They are geographically separated and have different organizational structures. (2) The PC enterprise architectures (EA) are in the business silo stage. Each PC's information stores and tools serves its own local needs, and they cannot meaningfully share. (3) CSE has begun working with the Development Planning working group. (4) CSE has initiated working groups. Recommendations for CSE: (1) PCs move toward a Coordination Operating Model. (2) PCs move from stage 1 to stage 3 or 4 for their EA. (3) CSE become vehicle to move to a coordination operating model and an enhanced EA stage. (4) CSE foster planning for compliance with new DoD policy/guidance regarding information sharing and interoperability. (5) CSE continue working with PC working groups.

15. SUBJECT TERMS
Collaborative Early Systems Engineering, Air Force Product Centers, Center for Systems Engineering

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